The contribution of coping related variables and cardiac vagal activity on prone rifle shooting performance under pressure

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Abstract

The aims of this study were to assess the predictive role of coping related variables (CRV) on cardiac vagal activity (derived from heart rate variability), and to investigate the influence of CRV (and cardiac vagal activity) on prone rifle shooting performance under low pressure (LP) and high pressure (HP) conditions. Participants (*n* = 38) competed in a shooting task under LP and HP. Cardiac vagal activity measurements were taken at baseline, task and recovery for 5 minutes, alongside ratings of stress via a visual analogue scale. Upon task conclusion, self-report measures of motivation, stress appraisal, attention, perceived pressure and trait CRV questionnaires (Decision Specific Reinvestment Scale, Movement Specific Reinvestment Scale and Trait Emotional Intelligence Questionnaire) were completed. Results indicated that task cardiac vagal activity was predicted by resting cardiac vagal activity and self-control, in HP and LP. Post task cardiac vagal activity was predicted by resting cardiac vagal activity in both conditions with the addition of a trait and state CRV in HP. Cardiac vagal reactivity, the change from resting to task, was predicted by resting cardiac vagal activity and self-control in LP and HP. Cardiac vagal recovery, the change from task to post task, was predicted by a trait CRV in HP. Shooting performance was predicted by experience and cardiac vagal activity in LP and cardiac vagal activity and a trait in HP. Findings suggest both CRV and cardiac vagal activity influence cardiac vagal activity throughout a pressure task. Additionally, shooting performance directly influences cardiac vagal recovery.

Keywords: Psychophysiology, cardiac vagal activity, pressure, self-regulation, shooting

1. Introduction

It is well established that an individuals' performance during aiming tasks such as dart throwing, golf putting and shooting can suffer from a decrease in performance under pressure (Oudejans, Binch, & Bakker, 2013; Nibbeling, Oudejans, & Daanen, 2012; Schucker, Hagemann, & Strauss, 2013; Williams & Cummings, 2012). In particular, shooting is of interest as individuals performing the skill have to shoot with speed and accuracy under pressure for example, athletes, police and army samples (Landman, Oudejans, & Nieuwenhuys, 2015; Thompson, Swain, Branch, Spina, & Grieco, 2015; Brisinda, Venuti, Cataldi, Efremov, Intorno, & Fenici, 2014; Vickers & Lewinski, 2012; Vickers & Williams, 2012; Causer, Bennett, Holmes, Janelle, & Williams, 2010; Ouedjans, 2008; Konttinen, Lyytinen & Viitasolo, 1998). Athletic shooting differs from firearms based shooting regarding the origin of pressure, as firearms professionals have to face life threatening scenarios (Vickers & Lewinski, 2012) whereas in athletic shooting, pressure mainly stems from performance. Shooting can be described as a "sport of the mind" due to its heavy reliance on mental skills (Coleman, 1980). The majority of studies demonstrate that pressure can affect different mechanisms involved in shooting such as gaze (Vickers & Williams, 2012; Vickers & Lewinski, 2012), cardiac activity (Thompson et al., 2015; Brisinda et al., 2014), psychomotor regulation (Konttinen et al., 1998) and gun motion (Causer et al., 2010); which ultimately may result in altered shooting performance. Furthermore, the individual characteristics of the shooter can affect performance under pressure, for example level of expertise (Landman et al., 2015; Vickers & Lewinski, 2012), state anxiety (Causer et al., 2010) and personality traits (Landman et al., 2015). Shooting performance under pressure can also be positively affected by level of experience (Vickers & Lewinski, 2012) or previous training under pressure (Nieuwenhuys & Oudejans, 2011). Pressure can have many effects on individual shooting performance. Recently research has started to examine a range of coping related variables simultaneously in order to further understand performance under pressure (Mosley, Laborde, & Kavanagh, 2017; Laborde et al., 2015). These coping related variables include trait emotional intelligence (Laborde, Brull, Webber, & Anders, 2011), reinvestment (Laborde et al., 2014), challenge and threat appraisal (Laborde, Lautenbach, & Allen, 2015), and cardiac vagal activity (Mosley et al., 2017; Laborde et al., 2015; Laborde, Furley, & Schempp, 2015). Thus, investigating variables that exist within different scientific domains that directly focus on the personal characteristics of the shooter may prove valuable in order to better understand shooting performance under pressure. Subsequently, the purpose of the study was twofold, 1) to examine the effects of coping related variables (trait emotional intelligence, reinvestment, appraisals, and cardiac vagal activity) on cardiac vagal activity under pressure and 2) to examine the effects of cardiac vagal activity and subjective coping related variables (trait emotional intelligence, reinvestment, and appraisals) on athletic shooting performance.

Cardiac Activity and Shooting

Within shooting research, heart rate is often a focus due to the stationary nature of the sport, if examining stationary target shooting, making it a closed skill when performed indoors. Given there is almost no movement when performing the skill, heart rate is not considered to be influenced by movement but mainly psychological processes due to autonomic nervous control (Levenson, 2014). It has been demonstrated that higher heart rate and blood pressure may impair shooting performance (Fenici, Ruggieri, Brisinda, & Penici, 1999) and slower deceleration of heart rate before shooting was linked to optimal shooting performance (Bertollo et al., 2012). However, studies only assessing heart rate cannot directly inform researchers about psychophysiological reactions to pressure. This is because heart rate alone is influenced by many factors (Levenson, 2014) and does not provide information about autonomic flexibility, which can represent higher order controls such as regulated emotional responding (Applehans & Lueken, 2006). One measure that enables researchers to understand how an athlete reacts to stress (Laborde et al., 2011), regulates emotion (Thayer, Ahs, Fredrikson, Sollers, & Wager, 2012) and performs under pressure (Laborde et al., 2015) is cardiac vagal activity.

Cardiac vagal activity represents the contribution of the parasympathetic nervous system to cardiac function (Laborde et al., 2017) and is a measure derived from heart rate variability (HRV); the change in the time interval between successive heart beats (Camm et al., 1996; Akselrod, Gordon, Ubel, Shannon, Barger, & Cohen, 1981). Cardiac vagal activity can index the efficiency of the central-peripheral neural feedback mechanisms, as postulated by the neurovisceral integration model (Thayer, Hansen, Saus-Rose, & Johnsen, 2009). This means that it may serve as a measure of an individual's ability to self-regulate through the organisation of physiological resources and response selection when in a changing environment (Thayer & Lane, 2000). Higher levels of cardiac vagal activity are suggested to be beneficial as the individual has greater behavioural flexibility and adaptability, whereas lower levels are suggested to be detrimental to adaptation in changing environments (Thayer et al., 2009). Cardiac vagal activity can be measured at different time points, which are called tonic measurements, taken over a period of time to provide an average cardiac vagal activity measurement (Laborde et al., 2017). Laborde and colleagues (2017) suggest that this is taken at three stages: rest, task, and post-task which directly reflects the three R's of cardiac vagal activity functioning: resting, reactivity, and recovery.

Tonic measures are deemed to be important particularly at rest as it is theorised that higher levels of resting cardiac vagal activity are more beneficial for stress management and emotional regulation (Thayer et al., 2009). Therefore, it is predicted that tonic task and post-task cardiac vagal activity variables will be positively related to resting cardiac vagal activity due to its role in effective self-regulation. It is important to consider that in order to determine the adaptation of the system when demand is placed upon it, tonic measurements alone are not sufficient (Thayer et al., 2012). Therefore, it is important to consider the change between tonic measurements which is known as phasic cardiac vagal activity. Phasic cardiac vagal activity can be split into two variables, reactivity and recovery. Cardiac vagal reactivity is the change from the resting state to the onset of a task (Park, Vasey, Van Bavel, & Thayer, 2014). Cardiac vagal recovery is from the removal or end of the task to the post-task state (Laborde et al., 2017). By assessing phasic cardiac vagal activity, we can understand how the individual is regulating themselves under pressure. Importantly, tonic and phasic levels may influence each other, as higher levels of tonic cardiac vagal activity at rest have been found to positively influence phasic cardiac vagal reactivity (Park et al., 2014). This can be explained because tonic cardiac vagal activity allows for better self-regulation in stressful situations (Thayer et al., 2009).

Cardiac vagal activity and shooting

It is important to consider the role of cardiac vagal activity in differing tasks and situational demands. When tasks involve executive functioning a smaller vagal withdrawal is seen to be effective but if there is more metabolic demand a larger vagal withdrawal is seen to be effective (Thayer et al., 2009). Cardiac vagal activity has rarely been assessed within shooting performance and it is important to understand how cardiac vagal activity may influence shooting performance. Brisinda and colleagues (2015) assessed live cardiac vagal activity reactions of police officers at rest and during simulated medium stress and high stress scenarios. They did not find any significant results when comparing rest and medium stress scenarios. However, they did note an increase in cardiac vagal activity (through high frequency heart rate variability) in high stress scenarios when compared with medium stress scenarios. This was linked to a potential "shut off" of the sympathetic system and increase in vagal activity when faced with short term life threatening danger (Fenici, Brisinda, & Sorbo, 2011), which could potentially be linked to effective self-regulation under stress (Thayer et al., 2009). A similar study by Thompson and colleagues (2015) found that participants who had a smaller reduction in cardiac vagal reactivity (from baseline to task) performed better, one element of better performance was taking less time to complete the shooting task. Most recently a study by Gross, Hall, Bringer, Cook, Killduff, and Shearer (2017) assessed the use of HRV biofeedback training in an elite shooting athlete. Cardiac vagal activity was manipulated during competition through slow paced breathing and was linked to subjective feelings of optimal performance (Gross et al., 2017). Based on the current theory surrounding self-regulation (Thayer et al., 2009) and previous empirical results (Thompson et al., 2015) it is predicted that a smaller reduction of cardiac vagal activity during the shooting task will be beneficial to shooting performance.

In sum, there have been limited efforts to examine the role cardiac vagal activity plays in shooting performance. There have been some insightful results, although the validity of some of the findings could be questioned due to the measures of HRV used (Thompson et al., 2015). Moreover, the focus seems to be surrounding firearms based shooting, such as police and army samples, while athletic shooting performance has currently received less attention. This study aimed to address this gap, considering athletic shooting performance in relation with cardiac vagal activity, based on clear psychophysiological theory, namely the neurovisceral integration model (Thayer et al., 2009). In addition to physiological measures such as cardiac vagal activity, it is important to consider the role of other psychological coping related variables that may have an influence on shooting performance, such as personality.

Trait Coping Related Variables and Shooting Performance

Personality traits are deemed to be stable over time and may directly influence performance under pressure (Mosley & Laborde, 2016). Shooting athletes are said to have differing personality traits according to discipline (Coleman, 1980) and more recently officers under pressure who were called to more violent situations scored higher in sensitivity to threat (Landman et al., 2015). In the interest of psychophysiology, it is already known that other personality traits can affect cardiac reactions under stress such as reinvestment and trait emotional intelligence (Mosley & Laborde, 2015; Laborde et al., 2015; Laborde et al., 2014), therefore those traits will be investigated in the current study.

Reinvestment is defined as the “manipulation of conscious, explicit, rule based knowledge, by working memory, to control the mechanics of one's movements during motor output” (Masters & Maxwell 2004, p. 208). Reinvestment has been shown to influence performance under pressure through two facets: movement (Masters & Maxwell, 2008) and decision (Kinrade, Jackson, Ashford, & Bishop, 2010). Studies have shown that higher levels of movement reinvestment have a negative effect on performance under pressure due to their propensity to consciously control previously learnt skills when placed under pressure (Jackson, Ashford, & Norsworthy, 2006; Otten, 2009). In a similar vein, decision reinvestment is defined as overthinking, through consciously controlling thoughts and/or ruminative thoughts, which is caused by high levels of cognitive effort that negatively affects performance (Kinrade et al., 2010). This has been shown in a decision making task (Laborde et al., 2014) and a simulated basketball task (Kinrade, Jackson, & Ashford, 2015). Decision reinvestment has also been linked to cardiac vagal activity and those higher in the trait suffer larger declines in cardiac vagal activity when under pressure (Laborde, Raab, & Kinrade, 2014). Therefore, it is predicted that decision reinvestment will have a negative influence on cardiac vagal activity during the task.

Another trait associated with performance under pressure is trait emotional intelligence, which represents a constellation of emotional perceptions (Petrides, Pita, and Koka, 2007). Trait emotional intelligence has shown to have facilitative effects under pressure as it can help to buffer the physiological stress response (Laborde et al., 2011) and facilitate coping (Laborde et al., 2015). In relation to sports performance trait emotional intelligence has shown links to performance satisfaction through coping (Laborde, Dosseville, Guillen, & Chavez, 2014), more facilitative appraisals when under pressure (Laborde et al., 2014), and an increased use of psychological skills to regulate emotion during competition (Lane, Thelwell, Lowther, & Devenport, 2009). In relation to physiology it has been found to predict cortisol secretion within a pressurised tennis serve task (Laborde et al., 2014) and has been shown to be a buffer for stress reactions as indexed by HRV (Laborde et al., 2011) and to positively influence resting levels of cardiac vagal activity (Laborde et al., 2015). Therefore, it is predicted that higher levels of trait emotional intelligence will positively influence resting and task cardiac vagal activity.

State coping related variables and shooting performance

In addition to trait variables, it is also important to understand the subjective evaluation of psychological components involved with coping related variables. Specifically, we focus here on challenge and threat appraisals, which have been shown to play a role within sporting performance under pressure. Challenge and threat appraisals allow for an understanding of demand and resource evaluations within a pressurised environment (Tomaka, Blascovitch, Kelsey, & Leitten, 1993). It has been shown that challenge appraisals are associated with successful sporting performance such as before a golf competition (Moore, Wilson, Vine, Coussens, & Freeman, 2013). Elite shooters were more likely to have negative appraisals before or after the shooter missed a target and positive appraisals followed after emotion and problem solving coping (Calmeiro, Tennenbaum, & Eccles, 2014). Although this study did not use the challenge and threat appraisal ratio, it still acknowledges the appraisal process within elite shooters. It is predicted that challenge appraisal will positively influence shooting performance.

The present study

In summary, current research shows that different coping related variables (cardiac vagal activity, reinvestment, trait emotional intelligence, and challenge and threat appraisals) may influence cardiac vagal activity and shooting performance under pressure. The combination of variables is still relatively under researched with some studies only combining one or two variables to determine performance under pressure (e.g. Laborde et al., 2015). Given no study has investigated all factors together this study has two aims: 1) to examine the effects of coping related variables (cardiac vagal activity, reinvestment, trait emotional intelligence, and appraisals) on cardiac vagal activity under pressure and 2) to examine the effects of cardiac vagal activity and subjective coping related variables (reinvestment, trait emotional intelligence, and appraisals) on athletic shooting performance. The hypotheses for the current study are as follows: Hypothesis one: Task and post-task cardiac vagal activity variables will be positively correlated with resting cardiac vagal activity and post-task cardiac vagal activity will be positively correlated with task cardiac vagal activity. Hypothesis two: Resting cardiac vagal activity will be positively related to cardiac vagal reactivity and recovery. Hypothesis three: A smaller reduction of cardiac vagal activity from baseline to task will be positively associated to shooting performance. Hypothesis four: Decision reinvestment will have a negative correlation with cardiac vagal activity during the task. Hypothesis five: Higher levels of trait emotional intelligence will be positively correlated with resting and task cardiac vagal activity. Hypothesis six: Challenge appraisal will positively influence shooting performance.

2. Methods

2.1. Participants

38 competitive prone rifle shooters (30 male and 8 female, M^{age}=55 years old, SD=14.8) completed the research task at a national competition. Shooting athletes were competing for a mean of 31.1 (SD=20.5) years' and participated at a range of levels (international=11, national=12, regional=2, county=13).

2.2. Research design

The study used a within subject design which are highly favoured in heart rate variability research as it allows for optimal experimental control, helps to reduce individual differences in respiratory rate, require fewer participants and help to reduce the impact of external variables such as smoking (Laborde et al., 2017; Quintana & Heathers, 2014). Within subject design can foster learning effects of task and habituation of conditions (Laborde et al., 2017), however, this can be reduced through the use of counterbalancing conditions (Laborde et al., 2017). In the current study participants participated in the same task across two different pressure conditions, low and high, which were counterbalanced.

2.3. Measures

2.3.1. Personality measures

The Trait Emotional Intelligence Questionnaire (TEIQue, Petrides, & Furnham, 2003) measures emotional intelligence as a trait. It assesses four main factors: well-being, self-control, emotionality and sociability and has 153 items. It is scored on a seven-point Likert-scale from 1 = completely disagree to 7 = completely agree (Petrides & Furnham, 2003). A sample items includes "I often find it difficult to recognise what emotions I'm feeling". It was deemed a reliable scale within the current study (global score α=.92, wellbeing α=.80, self-control α= 75, emotionality α=.77, sociability α=.83).

The Movement-Specific Reinvestment Scale (MSRS) was used (Masters & Maxwell, 2008). The MSRS is a nine-item scale and was deemed reliable in the current study (α=.87). Items are rated on a five point Likert scale which ranges from 1 strongly agree to 6 strongly agree and a sample item includes "I am always trying to think about my movements when I carry them out".

The Decision-Specific Reinvestment Scale (DSRS) by Kinrade and colleagues (2010) consists of 13 item measure, which was reliable in the current study (α=.84). It is rated on a 5 point Likert scale ranging from 0 not characteristic to 4 very characteristic. An example item includes "I'm always trying to figure out how I make decisions".

2.3.2. Cardiac vagal activity

HRV, from which cardiac vagal activity is derived, was measured using the eMotion Faros 180° (Mega Electronics Ltd, Pioneerinkatu, Finland). Sampling rate was set to 500hz as this is deemed to be a conservative sampling rate (Laborde et al., 2017). Three pre-lubricated disposable electrodes (Ambu VLC-00-S/25, Ambu GmbH, Bad Nauheim, Germany) were placed on the body, one below both left and right clavicles and one on the left side of the chest below the 12th rib.

2.3.3. Perceived Stress Intensity

A visual analogue scale (VAS) was used to reflect stress intensity, on which participants placed a cross on a 100mm line on "how stressed they felt as the present moment" which was anchored from "not at all stressed" to "extremely stressed" (Lesage, Berjot, & Deschamps, 2012).

2.3.4. Cognitive Appraisal

Two items from the cognitive appraisal ratio were used (Tomaka, Blascovitch, Kibler, & Ersnt, 1997). Participants were asked "How demanding did you feel the task was?" and "How able were you to cope with the demands of the task?" and were rated on a 6 point Likert scale rated from 1 (not at all) and 6 (extremely).

2.3.5. Perceived Pressure

The pressure/tension subscales were utilised from the intrinsic motivation inventory (Ryan, 1982). Participants rated four items such as "I felt pressured while doing the task" on a Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree).

2.3.6. Attention VAS

A VAS was also used to measure the direction of attention during the task. Participants were asked to place a cross on the line to determine where their attention was focused during the task. Two VAS scales were used, the first was anchored by the phrases "towards the task" and "away from the task", the second was anchored by the phrases "towards self" and "away from self", which was based on a suggestion from previous research (Laborde et al., 2015).

2.3.7. Motivation and effort

Participants completed a single item indicating "How motivated were you to perform to your best in this task?" on a 6 point Likert scale from 0 (not at all) to 5 (very much so).

2.3.8. Shooting performance

In order to create an appropriate task and pressure manipulations for shooting performance expert opinion was sought on the development of the task. The experts were two athletes competing at international level for 16 years combined and a shooting marshal who previously worked at the Olympic Games. Shooting performance was measured through a simulated competition that consisted of two trials of 10 shots each to be fired in a 5 minute time frame. A similar study, examining the effects of pressure of gaze in biathletes, used a comparable 10 shot procedure (Vickers & Williams, 2007). The shooting competition was held at a national shooting centre in Bisley (England) during a national rifle event. The shooting range used electronic targets which automatically calculated the score and therefore shooting score is classed as the total score of the 10 shots fired.

2.4. Procedures

2.4.1. Pre-testing procedures

Ethical approval was granted from the university ethics board. Participants were recruited at a national meeting through posters and announcements to participate in "heart rate" research that would be a separate competition held at the national meeting. Participants signed up to show their interest to participate at the national centre reception at which there was an information sheet participants were prompted to read. The information sheet prompted participants to refrain from heavy exercise 24 hours before attending the testing session and to avoid consuming caffeine and food two hours before the session. This is in order to avoid any confounding effects on heart rate activity during the testing (Laborde et al., 2017).

2.4.2. Participant preparation

Upon arrival to the range all participants provided written informed consent. Participants were told to set up their own shooting area, use their own gun, ammunition, and wear their normal shooting attire. Participants then had the three electrodes attached and the Faros 180° device was turned on to begin recording. Once the device was attached the participant was invited to lay on their shooting mat in a comfortable prone position, eyes closed and hands to their sides, to take a resting HRV reading for five minutes. The resting measure was taken in the prone position to ensure the baseline was the same to the position in which the task was carried out (Laborde et al., 2017). After the rest-period the first stress VAS was taken.

2.4.3. Performance

Participants were introduced to the competition structure: two trials of 5 minutes were completed in which individuals had to fire 10 shots, with 2 practice shots before each trial to adjust to conditions, also known as "sighters". Before commencing the trials, pressure manipulations were introduced as the competition conditions. Pressure manipulations were developed in line with Baumeisters (1984) recommendations and were developed with the international shooters and marshal. To initiate the start, the pressure script was handed to participants to read and the experimenter checked for understanding of the competitive condition. In the low pressure condition participants were told about the competition, monetary rewards for superior performance and interviews for the worst performers. The participants were then instructed to start the task and were not interacted with whilst performing. Once the 5 minutes had passed participants were instructed to put down their guns and make them safe. They then completed a stress VAS and a 5 minute HRV measure was taken whilst prone. After this they filled in a battery of subjective questionnaire (stress VAS, perceived pressure, cognitive appraisal, attention direction and motivation).

In the high pressure condition the competitive trial remained the same (5 minutes to fire 10 shots), however, additional conditions were added to increase the pressure to perform well. For example, any shots fired below a 7 were scored as zero and the 10th and final shot was worth double points. The adjustments in shot score were not actually taken into account in the final analysis to ensure the task outcome remained the same. In addition to the trial conditions the script included the scores being published on a national shooting website. In addition, the performance was filmed and participants were told the footage would be evaluated by national level coaches. During the task the experimenter made notes and the participants were told they were looking at facial expressions, body language and reactions to the task. After the second trial the participants were instructed to put down their guns and make them safe, fill in a stress VAS and a 5 minute HRV post task measure was taken whilst prone. Following this stage the participants filled in the battery of subjective questionnaires again (as in the low pressure condition). Participants were debriefed which included sending the battery of personality questionnaires (TEIQue, MSRS, DSRS) via email to be completed, they were subsequently thanked for their participation.

2.5. Data preparation

Firstly, the challenge and threat ratio was determined by dividing demands from resources (Tomaka et al., 1997) and all personality questionnaires were coded and scored accordingly. Secondly, heart rate variability data were processed for artefacts. The artefact correction function of Kubios was used, firstly the very low threshold was applied and data was visually inspected for artefacts that had been corrected, if any. Visual inspection of artefacts is deemed important in heart rate variability research to ensure they are correctly identified (Laborde et al., 2017). Secondly the low threshold was applied and data was visually inspected again to ensure artefacts were correctly being identified. If artefacts were highlighted and confirmed via visual inspection the artefact correction was applied at the low threshold level (1%). Next, indicators of cardiac vagal activity were extracted, in this study high frequency heart rate variability was used, which is between 0.15-0.4 Hz. The variable of high frequency absolute power derived from the Fast Fourier Transform was used, which is deemed a reliable measure for cardiac vagal activity (Laborde et al., 2017). Thirdly, data were first checked visually for normality via histograms and boxplots. If any outliers existed, they were winsorized (mean + 2x standard deviations). HRV variables were not normally distributed, therefore a log10 transform was applied, in line with procedures used in other research of this nature (Park et al., 2014). After data transformation data were checked again for normality and it was ensured they had a z score of between ±2.58 (Field, 2009), all variables were considered to be normally distributed.

2.6. Data analysis

To ascertain whether the pressure conditions were successful, a repeated-measures MANOVA was used with condition (low pressure vs. high pressure) set as the within subject factor and the subjective stress variables (Stress VAS after the task, pressure and tension subscales) as dependent variables. A pressure effect would be noted by higher ratings of stress after the task, higher ratings of pressure and lower ratings of relaxation in the high pressure condition when compared to the low pressure condition. To explore the contribution of coping related variables to cardiac vagal activity (resting, task, post task, reactivity and recovery) bivariate correlations were run followed by hierarchical stepwise linear regression analyses. Using a hierarchical regression the following were entered as dependant variables 1) resting, task, post task, reactivity, and recovery cardiac vagal activity, as well as 2) shooting performance under pressure. The first block included age, gender, shooting level, and experience, which allowed the researchers to control covariates. The second block was used to explore the contribution of coping related variables (reinvestment, trait emotional intelligence and, challenge and threat ratio) to cardiac vagal activity and the contribution of the coping related variables and cardiac vagal activity to shooting performance under pressure. When assessing any phasic variables, or when phasic variables were used as a predictor resting cardiac vagal activity was also controlled for in the first block of the hierarchical regression.

2.7. Preliminary checks

In order to ensure all participants were motivated to compete in both conditions, a one item measure asked “How motivated were you to perform to your best in this task?” on a 6 point Likert scale from 0 (not at all) to 5 (very much so). The participants appeared to be motivated in both the low pressure condition (M=4.15, SD=0.82) and the high pressure condition (M=4.21, SD=0.81). A paired sample t-test confirmed there was no difference between motivation in both conditions $t(37)=.627$, $p=.534$, $d = 0.101$. Breathing rate was also checked across conditions as many shooting athletes control their breathing when they shoot (Gross et al., 2017). This was to ensure participants did not change their breathing patterns across conditions which is important for two reasons. Firstly, slow paced breathing can directly affect cardiac vagal activity and secondly, there should be no differences in respiratory frequency between experimental tasks when drawing conclusions from cardiac vagal activity (Laborde et al., 2017). To do this the electrocardiogram derived respiration variable was obtained post-hoc from Kubios. This variable estimates respiratory frequency from the R-wave amplitudes which are known to change under chest movements related to respiration (Tarvainen, Niskanen, Lipponen, Ranta-aho, & Karajalainen, 2014). Therefore, an estimate of average respiratory rate across the task was compared across both low and high pressure conditions. A paired sample t-test confirmed there was no difference between breathing rate in both conditions $t(37)=-1.578$, $p=.123$, $d = -0.255$. Lastly in order to account for type one errors, the Benjamini-Hochberg correction (Bejamini & Hochberg, 1995) was applied to the correlations in the current study (Tables 2 and 3). For both high and low pressure correlations, the false discovery rate was set to .15.

3. Results

Firstly, descriptive statistics are reported in table 1 then correlation matrixes of all study variables are presented in table’s 2 and 3.

3.1. Descriptive statistics

Below are the descriptive statistics for the study.

Table 1: Descriptive Statistics

	M	SD
Age	55	14.8
Trait Variables		
DSRS	1.81	1.43
MSRS	2.26	1.36
Trait EI - Well-Being	5.28	1.31
Trait EI - Self-Control	5.42	.88
Trait EI - Emotionality	2.47	1.03
Trait EI - Sociability	5.05	.98
Trait EI - Global Score	4.50	1.65

Performance Variables	*High Pressure*		*Low Pressure*	
	M	SD	M	SD
Shooting Score	96.26	4.24	97.18	3.36
Attention Towards Task	18.05	22.63	19.00	23.02
Attention Towards Self	45.47	32.51	45.00	32.90
Perceived Demands	3.10	1.35	2.86	1.61
Perceived Resources	4.78	.90	4.57	1.34
Demand/Resource Ratio	.69	.37	.71	.54
Perceived Stress Post Task	34.15	17.82	31.89	20.77
Perceived Pressure Post Task	3.57	1.82	3.57	1.76
Perceived Anxiousness Post Task	2.81	1.6	3.1	1.59
Motivation to Compete	4.21	.81	4.15	.82

Cardiac Variables	*High Pressure*			*Low Pressure*		
	M	SD	Range	M	SD	Range
Resting CVA (LT)	2.53	.61	2.18	2.53	.61	2.18
Task CVA (LT)	2.53	.60	2.7	2.51	.62	2.54
Post task CVA (LT)	2.58	.71	2.95	2.42	.68	2.89
Reactivity CVA (LT)	-.006	.66	2.93	-.02	.61	2.23
Recovery CVA (LT)	.05	.71	2.97	-.09	.60	2.81
Resting CVA (Raw)	749.64	907.41	2807.13	749.64	907.41	2807.13
Task CVA (Raw)	645.06	712.74	2622.29	645.76	726.18	2644.60
Post task (Raw)	823.22	1020.99	3968.15	592.57	780.41	2764.17
Reactivity (Raw)	-104.57	913.54	4991.54	-103.87	779.71	4004.28
Recovery (Raw)	178.16	931.54	4612.88	-53.19	648.15	3534.51

Note: DSRS = Decision reinvestment total score; MSRS = Movement reinvestment total score; Trait emotional intelligence = Trait Emotional Intelligence; CVA = Cardiac Vagal Reactivity (High frequency absolute power obtained through the Fast Fourier Transform); LT= Log transformed cardiac vagal activity; Raw = Cardiac variables pre log transform, ms^2.

Table 2: Correlation Matrix for Low Pressure Conditions

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. DSRS	-														
2. MSRS	.23	-													
3. Trait EI - Well-Being	-.27	-.07	-												
4. Trait EI - Self-Control	.08	-.02	.19	-											
5. Trait EI - Emotionality	.09	.02	-.10	-.60**	-										
6. Trait EI - Sociability	-.03	-.13	.15	.59**	-.47**	-									
7. Trait EI - Global Score	.15	.15	-.08	-.22	.23	-.05	-								
8. Attention Towards Task	.28	-.17	.08	.35	-.22	.36*	.00	-							
9. Attention Towards Self	-.16	-.04	-.18	.28	-.28	.24	-.37*	.33	-						
10. Demand/Resource Ratio	.07	-.24	-.44**	-.06	.04	.11	-.07	.03	-.00	-					
11. Resting CVA	.16	.05	-.12	.07	-.06	-.15	-.04	-.10	.14	-.10	-				
12. Task CVA	.13	.07	-.04	.46**	-.41**	.27	-.07	.12	-.00	-.11	.50**	-			
13. Post task CVA	.21	.09	.04	.24	-.20	.18	-.11	.09	.14	-.20	.62**	.56**	-		
14. Reactivity CVA	-.02	.02	.07	.39*	-.34	.42**	-.02	.23	-.14	-.11	-.49**	.50**	-.04	-	
15. Recovery CVA	.10	.03	.09	-.20	.19	-.06	-.05	-.02	.17	-.10	.18	-.38*	.54**	-.56**	-
16. Shooting Score	.02	.15	.16	-.03	-.14	-.13	.06	.22	.16	-.37*	.20	.02	.39*	-.17	.42**

*p < .05; **p < .01

Note: DSRS = Decision reinvestment total score; MSRS = Movement reinvestment total score; Trait emotional intelligence = Trait Emotional Intelligence; CVA = Cardiac Vagal Reactivity (High frequency absolute power)

Table 3: Correlation Matrix for High Pressure Condition

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. DSRS	-														
2. MSRS	.23	-													
3. Trait EI - Well-Being	-.27	-.07	-												
4. Trait EI - Self-Control	.08	-.02	.19	-											
5. Trait EI - Emotionality	.09	.02	-.10	-.60**	-										
6. Trait EI - Sociability	-.03	-.13	.15	.59**	-.47**	-									
7. Trait EI - Global Score	.15	.15	-.08	-.22	.23	-.05	-								
8. Attention Towards Task	.12	-.19	.03	.01	.02	-.06	-.08	-							
9. Attention Towards Self	-.17	-.11	-.26	.22	-.21	.26	-.44**	.34	-						
10. Demand/Resource Ratio	.13	-.20	-.39*	-.14	.06	-.17	.04	.15	-.03	-					
11. Resting CVA	.16	.05	-.12	.07	-.06	-.15	-.04	.20	.19	-.06	-				
12. Task CVA	-.08	.08	-.05	.45**	-.41**	.31	-.20	.06	.11	-.02	.39*	-			
13. Post task CVA	.25	.24	.06	.21	-.08	.23	.20	-.00	-.14	-.17	.53**	.42**	-		
14. Reactivity CVA	-.22	.03	.06	.34	-.31	.43**	-.13	-.13	-.07	.04	-.56**	.53**	-.11	-	
15. Recovery CVA	.32	.16	.10	-.17	.26	-.03	.37*	-.06	-.24	-.16	.20	-.41**	.64**	-.56**	-
16. Shooting Score	.21	.04	.14	.12	-.18	.04	.07	.20	-.02	-.19	.15	-.12	.33	-.28	.43**

*p < .05; **p < .01

Note: DSRS = Decision reinvestment total score; MSRS = Movement reinvestment total score; Trait emotional intelligence = Trait Emotional Intelligence; CVA = Cardiac Vagal Reactivity (High frequency absolute power)

3.2. Pressure manipulation checks

The MANOVA showed a significant main effect for condition $F(3, 34) = 3.0001$, p =.032, η^2=.26. However, follow up ANOVA's did not show significant differences in the ratings. This was further investigated in separate paired samples t-tests to firstly compare subjective stress between baseline and task and secondly to compare subjective stress between baseline and recovery. There was a significant difference between subjective stress at baseline and task in both low $t(37)$=-6.169, p<.001, d = -1.001 and high pressure conditions $t(37)$=-8.024, p<.001, d = -1.302. In addition, there was a significant difference between subjective stress at baseline and recovery in the high pressure condition only $t(37)$=-2.111, p=.042, d = -0.343, suggesting participants found the high pressure condition subjectively harder to recover from.

3.3. The predictive ability of coping-related variables to cardiac vagal activity in low pressure

Correlations between all variables are reported in Table 2. As study variables were intercorrelated a series of hierarchical stepwise regressions were performed, the first block was to control for age and gender and the second block was to identify salient predictors (Table 4). Across all step one regressions age and gender had no effect on cardiac vagal activity. Each regression specifies the predictor variables that were entered at each point. For resting cardiac vagal activity all trait variables were entered at step two and no predictors were found. For task cardiac vagal activity all trait, state and resting cardiac vagal activity were entered at step two. The first factor extracted was the level of cardiac vagal activity at rest (adjusted R^2 = .23, p = .001). The second factor extracted was trait emotional intelligence self-control (adjusted R^2 = .17, p < .001). The two factors together predicted 40% of the variance in cardiac vagal activity at task. For post task all trait, state and resting and task cardiac vagal activity variables were entered at step two. The first factor extracted was cardiac vagal activity at rest (adjusted R^2 = .36, p < .001). The second factor extracted was cardiac vagal activity at task (adjusted R^2 = .08, p < .001). Taken together the two factors combined explained 44% of the total residual variance. For cardiac vagal reactivity, trait and state variables and resting cardiac vagal activity were entered at step two. Other cardiac vagal activity variables were excluded at this stage as reactivity is derived from the tonic cardiac vagal activity variables. The first predictor extracted was resting cardiac vagal activity (adjusted $R^2 = .21$, $p < .001$), the second predictor extracted was Trait emotional intelligence self-control (adjusted $R^2 = .18$, $p = .002$). Both predictors together accounted for 39% of the variance in cardiac vagal reactivity. For cardiac vagal recovery trait and state variables were entered at step two and other cardiac vagal activity variables were excluded at this stage as recovery is derived from the tonic cardiac vagal activity variables. There were no predictors for recovery.

Table 4 - Multiple (stepwise) Regressions for Cardiac vagal activity in Low Pressure

Model	Unstandardized coefficients		Standardized coefficients	*t*
	B	Std Error	β	
Task CVA				
1 Resting CVA	.50	.14	.50	3.47*
2 Resting CVA	.47	.12	.46	3.67*
Trait EI Self-control	.30	.08	.43	3.37*
Post task CVA				
1 Resting CVA	.68	.14	.62	4.73**
2 Resting CVA	.49	.15	.44	3.15*
Task CVA	.37	.15	.34	2.42*
Reactivity CVA				
1 Resting CVA	-.49	.14	-.49	-3.37*
2 Resting CVA	-.52	.12	-.49	-3.37**
Trait EI Self-control	.30	.08	.43	3.36*
Shooting Score				
1 Level of experience	-.94	.42	-.34	-2.23*
2 Level of experience	-.90	.39	-.33	-2.30*
Post Task CVA	1.88	.71	.38	2.63*

***p < .05; **p < .01**

Note: CVA = Cardiac Vagal Activity, Trait emotional intelligence = Trait Emotional Intelligence
If regressions had no predictors they were excluded from the table.

3.4. The predictive ability of coping-related variables to cardiac vagal activity in high pressure

Correlations between all variables are reported in Table 3 As study variables were intercorrelated a series of hierarchical stepwise regressions were performed: the first block was to control for age and gender and the second block was to identify salient predictors (Table 5). Across all regressions age and gender had no covariate effect on cardiac vagal activity. Each regression specifies the predictor variables that were entered at each point. For resting cardiac vagal activity all trait variables were entered and no predictors were found. For task cardiac vagal activity all trait, state and resting cardiac vagal activity variables were entered at this stage. The first factor extracted was trait emotional intelligence self-control (adjusted R^2 = .18, p = .004). The second factor extracted was the level of cardiac vagal activity at rest (adjusted R^2 = .12, p = .001). For post task cardiac vagal activity trait, state and resting and task cardiac vagal activity variables were entered. The first factor extracted was resting cardiac vagal activity (adjusted R^2 = .27, p < .001). The second factor extracted was trait emotional intelligence sociability (adjusted R^2 = .08, p < .001). The third and final factor extracted was attention towards the self (adjusted R^2 = .13, p < .001). Taken together the three factors combined explained 48% of the total residual variance in post task cardiac vagal activity. For cardiac vagal reactivity trait, state variables and resting cardiac vagal activity were entered at this stage, other cardiac vagal activity variables were excluded at this stage, as reactivity is derived from the tonic cardiac vagal activity variables. For cardiac vagal reactivity the first factor extracted was resting cardiac vagal activity (adjusted R^2 = .29, p <.001), the second factor extracted was trait emotional intelligence self-control (adjusted R2 = .14, p <.001). Taken together these variables accounted for 43% of the variance in cardiac vagal reactivity. For cardiac vagal recovery trait, state variables and resting cardiac vagal activity were entered at this stage, other cardiac vagal activity variables were excluded at this stage, as reactivity is derived from the tonic cardiac vagal activity variables. The first and only factor to be extracted from the model was decision reinvestment (adjusted R^2 = .08, p = .045).

Table 5 - Multiple (stepwise) Regressions for Cardiac vagal activity in High Pressure

Model	**Unstandardized coefficients**		**Standardized coefficients**	***t***
	B	Std Error	β	
Task CVA				
1 Trait EI Self-control	.31	.10	.45	3.10*
2 Trait EI Self-control	.29	.09	.43	3.13*
Resting CVA	.35	.13	.36	2.63*
Post task CVA				
1 Resting CVA	.62	.16	.53	3.83**
2 Resting CVA	.68	.15	.58	4.41**
Trait EI Sociability	.23	.09	.32	2.41*
3 Resting CVA	.79	.14	.68	5.53**
Trait EI Sociability	.31	.09	.43	3.49*
Attention towards self	-.00	.00	-.39	-3.09*
Reactivity CVA				
1 Resting CVA	-.61	.15	-.56	-4.08**
2 Resting CVA	-.64	.13	-.59	-4.79**

Trait EI Self-control	.29	.09	.38	3.14*
Recovery CVA				
1 DSRS	.16	.07	.32	-2.08*
Shooting Score				
1 Recovery CVA	2.59	.89	.43	2.89*
2 Recovery CVA	3.10	.88	.52	3.50*
Trait EI Emotionality	-1.31	.61	-.32	-2.15*

***p* < .05; ***p* < .01**
Note: CVA = Cardiac Vagal activity, DSRS = Decision reinvestment score, Trait EI = Trait Emotional Intelligence
If regressions had no predictors they were excluded from the table.

3.5. The predictive ability of coping-related variables and cardiac vagal activity on shooting performance in both low and high conditions

For performance, hierarchical stepwise regressions were performed, the first block was to control for age, shooting experience and shooting level and the second block was to identify salient predictors of shooting performance. Across all step one regressions age, experience and shooting level had no effect on shooting performance in the task. For performance prediction all trait, state and cardiac vagal activity variables were entered at this stage, regressions can be found in tables 4 and 5. The first regression performed was for shooting score in the low pressure. The first factor extracted was level of experience (adjusted R^2 = .09, p =.032), the second factor was post task cardiac vagal activity (adjusted R^2 = .13, p = .013). Both predictors together accounted for 22% of the variance in low pressure shooting score. The second regression performed was for shooting score in the high pressure condition. The first factor extracted was cardiac vagal recovery (adjusted R^2 = .16, p = .006), the second factor extracted was trait emotional intelligence emotionality (adjusted R^2 = .08, p = .003). Both together accounted for 24% of the variance in shooting score in the high pressure condition.

4. Discussion

The aim of this study was twofold: 1) to examine the effects of coping related variables (cardiac vagal activity, reinvestment, trait emotional intelligence, and appraisals) on cardiac vagal activity under pressure and 2) to examine the effects of cardiac vagal activity and subjective coping related variables (reinvestment, trait emotional intelligence, and appraisals) on athletic shooting performance. Findings will be discussed firstly in line with the predictors of cardiac vagal activity followed by the predictors of shooting performance.

4.1. Resting Cardiac Vagal Activity

Hypothesis five, predicting that trait emotional intelligence would be positively associated with resting cardiac vagal activity, was not supported. In both low pressure and high pressure conditions trait emotional intelligence global score and factors did not emerge as predictors for resting cardiac vagal activity. This prediction was based on previous research where trait emotional intelligence predicted resting cardiac vagal activity, in particular the subscale of wellbeing (Laborde et al., 2015). In contrast, other research exploring similar aims found no association with trait emotional intelligence and resting cardiac vagal activity (Mosley et al., 2017; Laborde et al., 2011).

4.2. Task Cardiac Vagal Activity

In both the low and high pressure conditions trait emotional intelligence self-control and resting cardiac vagal activity predicted task vagal activity, this is supports hypothesis five and hypothesis one. Shooters who had higher resting cardiac vagal activity had higher levels of cardiac vagal activity during the shooting task. High levels of cardiac vagal activity at rest positively influences adaptive emotional responding (Thayer et al., 2009; Ruiz-Padial, Sollers, Vila, and Thayer, 2003) and positive behavioural responses during tasks (Hansen, Johnsen, & Thayer, 2003), which is supported by previous research (Mosley et al., 2017; Park et al., 2014). Based on this, it could be suggested that individuals with higher resting cardiac vagal activity are better able to meet the demands of the task by successfully regulating themselves in stressful situations. This is directly complemented by the other predictor trait emotional intelligence self-control, which will be referred to as self-control from this point forward. Self-control is defined as the ability to regulate emotions, impulses and manage external pressure and stress (Petrides & Furnham, 2003). This may suggest individuals with greater self-control are better able to regulate themselves under stress, subsequently leading to higher cardiac vagal activity during stressful tasks. It has been shown that higher levels of cardiac vagal activity are linked to better emotional regulation (Park et al., 2014) which can be directly linked to the emotion regulation component of self-control (Petrides & Furnham, 2003). In addition, this further supports the notion that cardiac vagal activity is an index for self-regulation (Park et al., 2014; Thayer et al., 2012). An interesting point to note is the amount of influence in the low and high pressure conditions. In the high pressure condition self-control was the first predictor and in the low pressure condition it was the second. This may suggest that in high pressure conditions the trait of self-control may have a stronger influence on task cardiac vagal activity over resting levels of cardiac vagal activity. This could be supported by Landman and colleagues finding (2015) that self-control strength predicted perceived anxiety in the high pressure condition of a police shooting task. Higher anxiety was predicted by lower levels of self-control (Landman et al., 2015), therefore this may be directly associated with poorer self-regulation and reduced levels of cardiac vagal activity (Thayer et al., 2012).

4.3. Post Task Cardiac Vagal Activity

Hypothesis one predicted that resting cardiac vagal activity would positively influence task cardiac vagal activity and this was supported. In the low pressure condition post task cardiac vagal activity was predicted by resting and task cardiac vagal activity. An organism's recovery demonstrates the ability to face a stressful event and then return efficiently to resting level (Stanley, Peake, & Buchheit, 2013). These findings suggest higher levels of cardiac vagal activity at baseline fosters more effective recovery due to a greater initial capability to uptake self-regulation resources.

In the high pressure condition resting cardiac vagal activity was the first predictor. Additionally, trait emotional intelligence sociability and attention towards the self came out as predictors for post task cardiac vagal activity. Trait emotional intelligence sociability is defined as the ability to influence other decisions and emotions and also the capability to assert oneself (Petrides & Furnham, 2003). It could be suggested that individuals higher in sociability were better able to assert themselves in the high pressure condition where they had negative social influences i.e. the experimenter making notes and element of social evaluation. It has been suggested assertiveness and control over one's environment can be linked to stress resistance (Wallston, Wallston, Smith, & Dobbins, 1987), however this finding should be explored further. The final predictor was attention towards the self. The more the individual focussed away from themselves, perhaps towards irrelevant cue such as competitors or distractions, the lower the levels of post task cardiac vagal activity. The more attention paid towards the self promoted high levels of post task cardiac vagal activity. It may be that individuals who focussed on themselves made resources available to cognitively reflect on the task rather than sending energy to the body (Segerstrom & Nes, 2007), as during this time point the athlete would no longer be exerting physical effort in the task.

4.4. Cardiac Vagal Reactivity and Recovery

Hypothesis one was partially supported in that resting cardiac vagal activity predicted reactivity in the low and high pressure condition. However, the relationship between resting and reactivity was negative, in that the higher the resting levels the greater the drop from rest to task. It is important to note that the type of task that is being completed does not solely rely on executive function (Thayer et al., 2009) and therefore a withdrawal may be seen as adaptive and that this pattern is seen to be adaptive in prone rifle shooters. Interestingly self-control was seen to enhance cardiac vagal activity under pressure. This could imply that a large vagal withdrawal at the start of a competition allows shooters to meet the demands of the task. Following this, those high in self-control are able to enhance cardiac vagal activity after the initial onset of stress – which may subsequently lead to a better recovery. However, this needs further investigation and perhaps a detailed breakdown of the stages of competition, or shot by shot analysis.

Cardiac vagal recovery in the high pressure condition was predicted by decision reinvestment. The higher the level of reinvestment, the better the recovery from a stressful event. This finding does not support hypothesis four and contradicts the predictions of the trait, particularly as decision rumination that promotes the individual to think back to decisions they have made (Kinrade et al., 2010), which may be a process in recovery from stress. One explanation could be that as the stressor was removed at the point of recovery which prompted a relief, those higher in decision reinvestment display a higher cardiac vagal recovery level. It has been suggested that relief is linked to a decrease in sympathetic vascular influences and decreased breathing rates (Kreibig, 2010). It is well known that slowing breathing can positively influence cardiac vagal activity levels (Leher et al., 2013) and this breathing pattern is promoted by relief when the threat of danger is removed (Vlemincx, van Diest, Bressesleers, Bogaerts, Fannes, Wan, & van den Bergh, 2009). Consequently, more research into this finding is needed to shed light on the association of cardiac vagal recovery and decision reinvestment.

4.5. Shooting Performance

For shooting performance it was predicted that a smaller reduction of cardiac vagal activity during the task will positively influence shooting performance (hypothesis three), which was partially supported.

In the low pressure condition firstly level of experience came out as the first predictor. This finding suggested that the more experience the shooter has the better their performance, which is supported by previous research (Vickers & Lewinski, 2012). The secondary predictor of shooting performance in the low pressure condition was post task cardiac vagal activity. Better shooting performance promoted a higher level of post task cardiac vagal activity in recovery. A similar finding was discovered in the high pressure condition as the first predictor extracted was cardiac vagal recovery. The larger the decrease in cardiac vagal activity from task to post task the poorer the shooting performance was. Therefore, in both low and high pressure conditions the performance outcome from the shooting task directly influenced cardiac vagal activity after the task.

Previous research has supported the link between cardiac activity and shooting performance in elite pistol shooters (Bertollo et al., 2012), although Bertollo and colleagues examined individual shot performance rather than total score. They found that higher heart rate and slower deceleration occurred before moderate to poor shots and lower heart rate and earlier deceleration occurred before optimal shots (Bertollo et al., 2012). Although Bertollo and colleagues (2012) did not assess cardiac vagal activity or cardiac reactions during recovery, it demonstrates that poor shooting performance is directly linked to higher heart rate and optimal shooting performance is linked to slow and stable heart rate prior to performance. It could be suggested that optimal shooting performance prompts slower heart rate and thus increased cardiac vagal activity, which subsequently leads to better cardiac vagal recovery post shooting performance. It has also been noted that elevated high heart rates impair shooting performance (Vickers & Williams, 2007; Fenichi et al., 1999), which could lead to a poorer cardiac vagal recovery.

There has been very limited research surrounding cardiac vagal recovery and shooting performance, however recovery seems an important aspect in shooting sports. In shooting competitions athletes fire up to 60 shots which requires mental regulation throughout (Bortoli, Bertollo, Hanin, & Robazza, 2012; Prapavessiss, Grove, McNair, & Cable, 1992). Some of this regulation may come after negative experiences such as missed shots (Gross et al., 2017), which could be considered as part of the recovery process as it is an effort to return to resting level (Stanley et al., 2013). In addition, an observation from the time spent at the shooting range by the primary researcher was that many shooters take rest during competition to break up 60 shot matches. It may be that this time could be used more wisely by shooting athletes, particularly for those who have not performed well. Practitioners working within shooting sports should uncover what athletes do during recovery time to make it most beneficial to performance.

The secondary predictor of shooting score in the high pressure condition was trait emotional intelligence – emotionality. The findings suggested that those lower in emotionality had a better score in the high pressure condition. Typically, it is expected that higher emotionality would promote better performance due to the nature of the trait in recognising ones' emotions (Petrides, 2009). However, it may be that in shooters the ability to ignore or be unaware of your emotional state during high pressure competitions may be more beneficial. This may also link to other findings linked to trait emotional intelligence in this study as self-control played a role at various points. Therefore, it may be that training shooters in self-control is more vital to performance than emotionality, however this would need to be investigated further.

4.6. Limitations

There are some limitations that need to be considered in light of the current study. Firstly, the pressure manipulations may have not been fully effective in creating a high and low pressure condition. One reason for this may be that although shooters were aware of the extra pressure (i.e. making notes, being filmed), because of the safety of live firing ranges these had to be performed in the peripheries of the athletes. Some athletes also wear caps to block out external stimuli so this could have stopped them from being exposed to the high pressure manipulations, although they were still psychologically aware of them. This is a limitation of collecting data in ecologically valid settings, however in future other shooting or aiming tasks could be assessed to allow for full pressure manipulation to be carried out (i.e. Turner, Jones, Sheffiled, Slater, Barker, & Bell, 2013).

Sample size was a limitation within the current study. Given the nature of opportunistic and purposive sampling of the study being held at a national shooting competition, it was difficult to ascertain a large sample. Therefore, we used a posteriori analysis to calculate the minimum effect size that can be reliably detected with the current sample size, which was $f^2 = .47$. A further limitation could be the attrition of sample based on the personality scores being taken afterwards. In future research participants should answer personality questionnaires straight away in order to avoid sample size being affected. In line sampling the sample had a range of level of competitors and year's experiences and it has been shown in other research that experience plays a role in shooting performance under pressure (Vickers & Lewinski, 2012). In the current study this was controlled for in the analysis and was not found to affect the results, however future studies may wish to look solely at one shooting level.

Another consideration is that shooting sports naturally lend themselves to controlling breathing whilst performing the skill and controlled breathing is noted to have an influence over heart rate variability measurements (Malik, 1996; Berntson et al., 1997). In the current study a post-hoc analysis was used to control for breathing influences on heart rate variability measurement during the task and this method has been highlighted to have limitations (Laborde et al., 2017; Quintana & Heathers, 2014). The breathing measure was also an average respiratory rate during the task and would not have accounted for the changes in respiratory frequency across the course of the task. Future studies should look to use more advanced methods of assessing breathing during the task, such as using a strain gauge, which measures inhalation and exhalation via thorax dilation (Quintana & Heathers, 2014). This would allow respiration patterns of inhalation and exhalation to be identified across the course of competition. Ultimately this would increase reliability of the results and to better understanding the influence of breathing on heart rate variability measurement (Laborde et al., 2017). In addition to breathing, body mass index has been shown to affect heart rate variability measurements (Yi, Lee, Shin, Kim, & Ki, 2012). This variable was not assessed in the current study and should be systematically assessed in future research to avoid confounding effects.

5. Conclusion

To conclude, this study has furthered the knowledge surrounding the contribution of coping related variables to cardiac vagal activity across a pressured situation. At the theoretical level, we have strengthened the link between resting cardiac vagal activity and other tonic points (task and post task) throughout stressful tasks. This further affirms the link between resting cardiac vagal activity and self-regulation in situations requiring stress management and emotional regulation (Thayer et al., 2009). In addition we noted a relationship between self-control and task cardiac vagal activity in both low and high pressure conditions. It may be an interesting avenue to explore training self-control, as it has been shown that trait emotional intelligence can be trained (Campo, Laborde, & Mosley, 2016), to see if this can assist those with poor self-regulation under pressure. We also showed that cardiac vagal activity was directly linked to shooting performance. Specifically better post task and recovery levels were associated with better shooting performance. Not only does this strengthen the need to assess the three R's of cardiac vagal activity (Laborde et al., 2017), it shows that cardiac vagal activity has a larger influence on performance than subjective coping related variables. This indicates the importance of using physiological and psychological measures in order to gain a holistic view of performance and should be used in future pressure research.

At the applied level findings show the importance of understanding what athletes do during recovery periods after both successful and unsuccessful performances in sports that have changes in momentum. Consultants should consider measuring cardiac vagal activity across a competitive event to map changes over the whole 60 shot period. This will enable practitioners to implement suitable interventions for effective recovery periods in shooting competition. This may also be paired with training self-control as it had a beneficial effect on task cardiac vagal activity. The enhancement of both self-control and task cardiac vagal activity may further support an athlete's ability to self-regulate under pressure.

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